Mapping Afrotropical birds: links between atlas studies and conservation priority analyses

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Maps of bird distribution intrinsically appeal to scientists and birders alike, but are also fundamental for attempts to assess the distribution of avian biodiversity. Distributional maps of African birds are found in many field guides[2*], in major studies on the avifauna of Africa[11,21,28], and in a number of country bird-based atlases[16]. Bird mapping is also being turned into a scientific art-form in the Atlas of the Birds of Southern Africa, to be produced by the Avian Demography Unit in the University of Cape Town in South Africa, and the data generated are being used for analytical studies[12,30].

Bird distributional data have featured strongly in analyses of vertebrate distributional patterns[3, 5]. Such data were also used in the groundbreaking work by BirdLife International (formerly the International Council for Bird Preservation), which has identified those areas of Africa important for bird conservation, based on concentrations of species with pre-assumed ranges of less than 50,000 km^2. The areas identified were termed Endemic Bird Areas; 19 were found in Africa south of the Sahara[13].

Although the EBA approach had provided the first methodologically consistent attempt to produce a map of avian endemism's distribution, and has been highly praised in some quarters, it has also been criticised within Africa[4]. This was largely due to the failure to identify areas of endemism for arid-adapted species with marginally larger ranges than the critical area defined, a problem which is inevitable with any discontinuous/threshold approach. A more general shortcoming of the EBA approach was that it used data from a predetermined list of bird species, and not all birds in Africa. Using data from all bird species had the advantage of allowing the identification of a minimum set of areas capable of achieving the objective of protecting all the birds in Africa in one, two, or another predefined number of areas[19,20,24,32].

Use of bird distributional data to understand bird distributional patterns and further refine conservation priority setting

In 1993, Tim Crowe and Helen de Klerk of the Percy FitzPatrick Institute in South Africa initiated a programme to map the distributions of all Afrotropical birds. In 1995 they were joined by members of the Danish Centre for Tropical Biodiversity who were aiming to map biodiversity patterns in Afrotropical vertebrates (mammals, birds, snakes, amphibians), butterflies and some plant groups. The aims of the combined programme are to present data on species-richness and species-endemism in these groups and investigate the potential causes of the patterns found, to look at the degree to which these patterns are congruent, see to what extent the biodiversity is protected (in conservation areas) or threatened (eg in areas of high human population) within Africa. In part, this effort is designed to be the first large-scale test of the extent to which the priorities for bird conservation are a good indication of the priorities for other groups of organisms[13], which has been challenged by other preliminary studies at a regional level[2]. However the programme also hopes to provide some insights into why the distribution pattern of Afrotropical birds is like it is, and what may be the underlying causes of the patterns. Thus the mapping exercise is closely coupled with various projects where general biodiversity hypotheses will be tested using molecular studies of population structure and species relationships.

Adequate maps of bird distribution are essential to this project, and the Percy FitzPatrick Institute in Cape Town and the Centre for Tropical Biodiversity in Denmark have been jointly producing these over the past three years. The maps produced so far build on those found in classical works[11,14,21,28], in regional Atlases[16], and from papers in the last 10 years issues of regional ornithological journals, eg *Malimbus* and *Scopus*. BirdLife International has also permitted the inclusion of information from their database of restricted-range species (<50,000 km^2 range) found in Africa, which considerably refines the distributions of these rare species. The personal knowledge of observers in South Africa and Denmark has also been utilised. However, it is apparent that, there are scores of ornithologists in Africa and elsewhere, with many years of field experience, who have not had the opportunity to assess the accuracy of the maps which have been produced. The authors would be delighted to receive input from ornithologists willing to check the accuracy of maps for countries/regions, or for particular groups of birds.

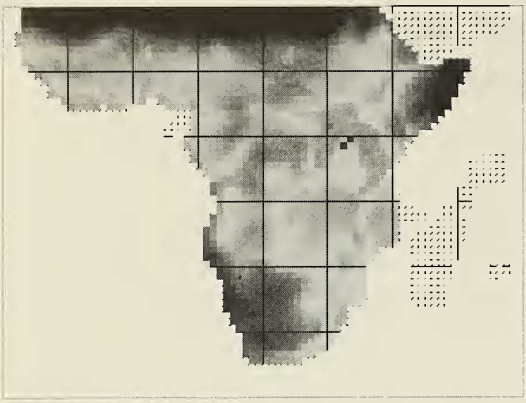

Fig 1a. Map of bird species-richness in Afrotropical Africa (based on computerised bird species distribution maps compiled from a variety of sources). Darkest areas = areas of low richness for birds (blue in original colour map, grading through green, yellow and finally red for the areas of increasing species richness).

Distributional data comprise both point locality records for all those species which have 'restricted range' in Africa, and interpolated range maps for the remaining species. Distributions are being mapped at the scale of a one degree square (approx. 110 km x 110 km). Maps for rare and range-restricted species consist of all known localities, whereas for more widespread and common species the distributional range has been conservatively mapped. The one degree square unit was selected by considering of the density of survey results from the poorest known regions of Africa (eg in the Congo Basin).

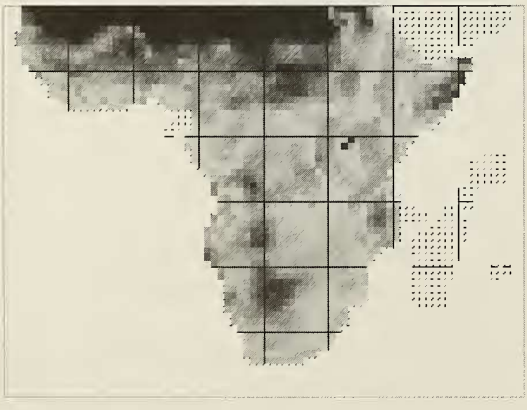

Fig 1b. Map of bird species-endemism in Afrotropical Africa (based on computerised maps compiled from a variety of sources). Darkest areas = areas of low endemism scores for birds (blue in original colour map, grading through green, yellow and finally red for the areas of increasing endemism scores).

Distributions are being computerised within the computer programme WORLDMAP Version 4.1 for Windows '95, developed by Paul Williams of The Natural History Museum in London, UK. This is a specialised platform for analysing species-richness, range-size endemism and the selection of priorities for conservation. WORLDMAP has been previously used to assess priorities for antelope conservation in Africa[15], and has been recently utilised in the production of a bird atlas for the United Kingdom[33].

Research possibilities

1. Visualising species-richness and species-endemism

By overlaying the individual maps, visual representations of species-richness and species-endemism can be produced. Such analyses illustrate broad patterns in the distribution of avian biodiversity in the Afrotropical Region.

The map of overall species-richness (Fig 1a) shows the well known high species-richness in eastern Africa, which is notable in comparison with the relatively low species-richness in the centre of the Congo rainforest and, especially, in the African deserts. Species-richness in northern parts of Mozambique, and in much of northern Angola are also low. This may merely be a reflection of the low effort made by ornithologists in these areas. Further data may produce species-richness scores in northern Mozambique similar to southern Tanzania.

The map of overall endemism (inverse range sizes) (Figure 1b) shows areas where species with restricted distributions concentrate. There is considerable overlap in the areas identified here with the Endemic Bird Areas map of BirdLife International, which was based on a sub-sample of Afrotropical birds. Statistical treatments of the computerised data are also possible and some possibilities being explored are outlined below.

2. Can bird data be used to understand evolutionary processes?

One of the aims for the bird map database is to attempt to map areas where species evolution is occurring (Type II refugia *sensu*[3]), and where species have persisted over long periods of time without giving rise to new species (Type I refugia *sensu*[3]). Birds are the only group of animals where such studies might be possible at the present time, because there has been considerable research into bird DNA, which provides an idea of the relative 'age' of the different bird species[26]. Provisional maps, illustrating the distribution of newly evolved and more ancient bird species

have already been produced for Africa[8]. A more comprehensive database of bird distributions, and further interpretation of DNA data, could lead to the identification of areas of Africa important for the evolution of new species.

3. Can patterns of bird biodiversity be explained in terms of environmental variables?

A recurring theme of research into Afrotropical bird faunas, is discussion of whether biotic (vegetation) and abiotic (climate, topography etc) factors can be used to explain patterns of species-richness and endemism in Afrotropical birds. The authors' work aims to build on previous studies[3,29], by using computerised species-distributional databases and the vast quantities of digitised data on biotic and abiotic attributes of Africa available, from the interpretation of satellite-derived information. Questions to be investigated using these data-sources are:

1) can the pattern be explained by topographical variation within Africa ?
2) can the pattern be explained by rainfall, temperature, humidity, seasonality in Africa?
3) is the pattern a reflection of productivity in Africa?

The degree to which these variables explain biodiversity patterns may help to understand their underlying causes. Also, the degree to which these variables do not explain the patterns may cast further light on whether the distribution of birds today is related to historical changes in the African continent, such as climatic change during the Ice Ages, or the emergence of volcanoes. Such studies are at an early stage, but initial results[9] show promise that satellite-derived climatic data may provide information relevant to explaining the distribution of narrowly endemic forest species.

Conservation possibilities

Identification of key areas for conservation

There are various approaches to the identification of the key areas for conservation. BirdLife's Endemic Bird Areas (EBA) and Important Bird Areas (IBAs) provide catalogues of areas requiring conservation attention. However, there are alternative approaches to defining conservation priorities. One such is complementarity, which selects areas based on their complement of species within a predefined objective, eg protecting all the birds of Africa in at least one area. This method produces a set of areas where conservation action is vital, if avian biodiversity is to be safeguarded.

Step-wise complementarity

The step-wise approach to complementarity creates a list of areas by selecting the most important area (in terms of species-richness or endemism), then excluding it from consideration (and all species it contains) and then selecting the next most important area. Although this approach makes a useful sequential selection of areas, it does not take account of statistical efficiency[31]. The highest ten ranked areas, identified using the step-wise complementarity approach, for bird richness (Table 1) and bird endemism (Table 2) identifies areas within those previously defined as EBAs by BirdLife International[13].

Table 1. Sequential list of the top ten areas (one degree grids) selected for richness using step-wise complementarity (of total 94 areas selected to represent all species in Africa).

Area	Grid Centre	Country	Geographical name	BirdLife EBA site
1	2.5°N 30.5°E	Zaïre	Northern Albertine Rift	yes – parts C19 & C20
2	4.5°S 39.5°E	Tanzania	East Usambaras	yes – parts C23 & C24
3	24.5°S 29.5°E	South Africa	Kruger National Park	yes – C28/C27 transition
4	4.5°N 9.5°E	Cameroon	Cameroon highlands /lowlands	yes – parts C04 & C05
5	15.5°N 39.5°E	Eritrea	Asmara area	yes – C16
6	12.5°S 14.5°E	Angola	Angola Scarp	yes – C08
7	0.5°S 36.5°E	Kenya	Mt.Kenya to Naivasha	yes – C21 (perhaps +C22)
8	7.5°N 8.5°W	Guinea/Liberia	Mt. Nimba	yes – C03
9	33.5°S 18.5°E	South Africa	Cape area	yes – C29
10	3.5°S 28.5°E	Zaïre	Southern Albertine Rift	yes – C20

Table 2. Sequential list of the top ten areas (one degree grids) selected for endemism using greedy complementarity (of total 84 areas selected to represent all species in Africa).

Area	Grid Centre	Country	Geographical name	BirdLife EBA site
1	3.5°S 28.5°E	Zaïre	Southern Albertine Rift	yes – C20
2	4.5°N 9.5°E	Cameroon	Cameroon highlands /lowlands	yes – parts C04 & C05
3	4.5°S 39.5°E	Tanzania	East Usambaras	yes – parts C23 & C24
4	12.5°S 14.5°E	Angola	Angola Scarp	yes – C08
5	7.5°S 37.5°E	Tanzania	Uluguru Mountains	yes – C24
6	9.5°N 39.5°E	Ethiopia	Shewa area	yes – C17
7	2.5°N 30.5°E	Zaïre	Northern Albertine Rift	yes – parts C19 & C20
8	0.5°S 36.5°E	Kenya	Mt. Kenya to Naivasha area	yes – C21 (perhaps +C22)
9	8.5°S 35.5°E	Tanzania	Udzungwa Mountains	yes – C24
10	6.5°N 8.5°W	Guinea/Liberia	Mt. Nimba	yes – C03

The areas are ascribed a name according to the most obvious recognisable place, or biologically unique area within the square selected.

Minimum set complementarity and assessments of the degree to which avian biodiversity is protected or threatened

The minimum set approach to complementarity is more efficient than the step-wise method in that it is able to choose fewer areas in order to achieve the same objective of representing all species in the distributional database. The iterative algorithms involved in such a process have been discussed widely elsewhere[7,19,23,32] and are the basis of considerable efforts being invested in conservation-priority setting in South Africa[6,18] and elsewhere in the world[10]. The minimum set approach for Afrotropical birds defines fewer areas which require protection, compared to the step-wise approach, but the highest priority areas selected are similar.

In terms of assessing the protection of biodiversity, there is currently great interest in attempting to assess the extent to which the current system of Protected Areas (typically IUCN category National Parks) conserve overall biodiversity. Several studies in South Africa[17, 18, 25], Australia[22] and South America[10] have demonstrated that existing Protected Areas, established over many years, typically using ad hoc and opportunistic approaches, are not wholly effective in protecting all species. These areas seem best for protecting populations of large mammals and less useful for protecting areas with greater levels of endemism, which also occur in smaller habitat blocks where the species have smaller, less visible and commercially less important populations.

A preliminary assessment of the degree to which the Afrotropical avifauna is well-protected indicates that the major (large scale) 'gaps' in the network of protected areas are in the Cameroon highlands, the Angola Scarp, the Eastern Arc Mountains of Tanzania, and the Albertine Rift Mountains of Central Africa. These areas have considerable overlap with those outlined in Tables 1 and 2.

The degree to which biodiversity is threatened is also important to determine when making conservation priorities and strategies. Various indices of threat are being developed around the world but the simplest is the human population pressure of an area. Human population data are of variable quality throughout Africa, and are often compiled in terms of large political units which makes them difficult to relate to biological data. However, threats data can be extracted from maps by looking for areas with 'high' and 'low' levels of human disturbance (eg density of road networks, numbers of settlements etc). Such data can then be used as an index of threat which can be compared to the species-richness and endemism of the same grid. Results of analyses being undertaken in Copenhagen and Cape Town indicate that bird endemism is very noticeably located in areas where human population density is highest. This is mainly because, in many places in Africa the endemic birds are found in forested areas on the tops of hills, which are also good places for water catchments required by large human populations at lower elevations where there is enhanced potential for food production and stable lifestyles.

Links between mapping biodiversity and atlas production

This paper outlines current developments in continuing attempts to map Afrotropical biodiversity. It is expected that considerable refinement of the birds database could be made using existing knowledge, and that useful analyses for scientists and conservationists can be undertaken using the database.

All such studies rely on the compilation of distributional data from existing literature and collaboration with the experts on the biodiversity of the area. The authors hope that more help can be enlisted to produce the best possible maps of Afrotropical bird distribution. However, this project only provides a starting point for what could be done with existing knowledge and unpublished information held by individuals, if these data were collected and input into a suitable point-locality database.

A project to atlas Afrotropical birds, either at the one degree or 0.5 degree level, for the Afrotropical Region or all Africa would be a major step forward in attempts to understand Afrotropical bird distribution and plan conservation. Such a study is a scientifically defensible goal for completion within the next 10 years. An atlas project requires cooperation between ornithologists throughout the continent, and would thus be a marvellous opportunity for collaboration, mutual training and learning.

Conclusions

- Existing knowledge on bird distribution can be used for both conservation planning and scientific research if distributional data are computerised. There is also potential to refine considerably available distributional data to make such analyses of greater use.
- Preliminary analyses of computerised bird data show the major centres of bird endemism and bird

species-richness. For endemism, the approach broadly confirms the areas selected as priorities by BirdLife International in their work on Endemic Bird Areas. However, if all the birds are considered in a minimum-set analysis, some other areas are also seen to be essential for Afrotropical bird conservation. Having the data on computer also permits further analyses to be performed which can indicate, in broad terms, areas with the greatest need for conservation action, and also where the birds are most threatened by human populations.

- The authors would be pleased to hear from ornithologists interested in Afrotropical bird distribution and conservation, particularly African Bird Club members. The greatest assistance would be from people willing to check our maps for an entire group of birds, or geographical region or country.
- We would also be pleased to lend our support to a scientific endeavour in Africa to compile distributional data for the production of an Atlas of Afrotropical birds. We believe this proposal has both scientific and conservation merit, and is a logical development of existing programmes in southern Africa and various other regions of Africa. It could also provide a new ornithological challenge for those scientific ornithologists involved with the current work on the production of a directory of African sites of high importance for bird conservation (Important Bird Areas), coordinated by BirdLife International. An Afrotropical Atlas would also provide an excellent opportunity for training additional ornithologists, something which is particular relevant in many tropical African countries where there may be as few as a single trained ornithologist.

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